

Protecting the environment through insect farming as a means to produce protein for use as livestock, poultry, and aquaculture feed

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Abstract

Securing protein for the approximate 10 billion humans expected to inhabit our planet by 2050 is a major priority for the global community. Evidence has accrued over the past 30 years that strongly supports and justifies the sustainable use of insects as a means to produce protein products as feed for pets, livestock, poultry, and aquacultured species. Researchers and entrepreneurs affiliated with universities and industries, respectively, from 18 nations distributed across North and South America, Europe, Asia, Africa and Australia contributed to the development of this article, which is an indication of the global interest on this topic. A brief overview of insects as feed for the aquaculture industry along with a review of the black soldier fly, *Hermetia illucens* (Diptera: Stratiomyidae), as a model for such systems is provided.

Keywords: conservation, *Hermetia illucens*, sustainable agriculture, waste management

Securing resources to provide protein needed to sustain the projected human population is a top priority of most governments (Godfray *et al.*, 2010). Estimated population growth from 2005 to 2050 indicates global food demand to increase by 100% (Tilman *et al.*, 2011), while agricultural production is projected to increase only by 60% (FAO, 2014b). The increase of global production of specific agricultural commodities will fall substantially short of what is needed to meet projected demands in 2050 (shortages of approximately 67, 42, 38, and 55%, for maize, rice, wheat and soybean, respectively) (Ray *et al.*, 2013). The global inability to sustain the necessary food production will emanate in increased duress of approximately 805 million undernourished people living in developing countries (FAO, 2014b; FAO *et al.*, 2012), which could lead to greater risk of local, national and global disease (Kau *et al.*, 2011).

Increasing crop production only represents a short-term solution and has been anticipated to negatively impact the environment on a large scale. For instance, nitrogen and phosphorus use is expected to increase by 40–50% due to increases in crop production, which will impact water quality (coastal and fresh water, fish kills), air quality (pollutants such as NH₃ and NO₂), soil degradation (loss of fertility and erosion), degradation of ecosystems (e.g. eutrophication), and biodiversity (loss of species) (Sutton *et al.*, 2013; Tilman, 1999). Greenhouse gas emissions from agriculture, forestry and other land use activities could increase 30% by 2050 (FAO, 2014a). To hold the increase in global temperature below two degrees Celsius and avoid ‘dangerous’ climate change, deep cuts in global emissions are urgently required (Gerber *et al.*, 2013).

Aquaculture is the fastest-growing animal food-producing sector globally (Subasinghe *et al.*, 2009) where production from both aquaculture and wild-capture will exceed that of beef, pork or poultry within the next decade alone (FAO, 2012). Fish are harvested from international waters to produce fishmeal, which is used as feed in the aquaculture

and livestock industry. In 2010, aquaculture utilised 73% of fishmeal and 71% of fish oil produced (FAO, 2014b). However, international fisheries are being over-exploited and current practices are not sustainable, which is evident as current production of fishmeal and fish oil has decreased from 30.2 million tons (live weight) in 1994 to 16.3 tons in 2012 (FAO, 2014b). Alternate sources of protein are therefore urgently needed to sustain the aquaculture industry.

The black soldier fly *Hermetia illucens* (Diptera: Stratiomyidae) represents one example of insect species such as housefly, mealworm and cricket that can be used for producing protein for use as livestock and fish feed and human food with minimum negative environmental impact and human health effects. This insect is able to convert organic by-products, such as food waste (~1.3 billion tons produced globally on an annual basis), which is an under-utilised sustainable resource (FAO, 2011) valued at 750 billion US\$ (The Economist, 2014). This insect, like many others, can also be used to recycle livestock waste, which is a concern for pollution as well (Sheppard *et al.*, 1994). It transforms ~50% dry matter of these organic side streams into insect biomass with a high protein value (Sheppard *et al.*, 1994). This insect is not a pest and is known to suppress pathogens of people and livestock. Furthermore, tons of this insect can be potentially produced daily in limited space using large industrial facilities. But it can also be produced by non-mechanised harvesting, which is important in developing nations of the world that rely heavily on human labour and have limited technological resources. We also know that the black soldier fly can successfully replace approximately 50% of the fishmeal used to produce rainbow trout (St. Hilaire *et al.*, 2007), and is a suitable replacement feed for a number of aquacultured species such as catfish, tilapia (Bondari and Sheppard, 1987) and salmon (Lock *et al.*, in press), and – outside of aquaculture – chickens (Hale, 1973) and swine (Newton *et al.*, 1977). Presently, resources are needed through government agencies to conduct the

necessary research to address concerns over food safety, optimal production, and utilisation of protein resulting from insect farming.

We hope that other scientists, policy makers, government officials and food production representatives will consider joining us through discussions on how to create opportunities to conduct research on this topic as to provide appropriate information to our legislators, and create momentum resulting in a cultural shift leading to legislative changes allowing for the use of such a promising sustainable resource to be explored and ultimately implemented. Application of insect farming for protein production would facilitate a means of supplying the materials needed for the production of pet, livestock, poultry and aquaculture feed and human food. In turn, such resources will allow us to face the challenges of the rapidly growing global human population. Insects as feed and food have great promise as a new agricultural sector, but there is an urgent need of a political and regulatory environment conducive for their use.

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Galley proof